Use of Regional Seismic Hazard Zonation in Earthquake Loss Reduction Policies. James F. Davis. California State Geologist. California Department of Conservation. Division of Mines and Geology

USE OF REGIONAL SEISMIC HAZARD ZONATION IN EARTHQUAKE LOSS REDUCTION POLICIES

by
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Abstract

This paper outlines the developmental history of seismic zonation in California--its present status; guidelines and regulations; current challenges and opportunities.

Seismic hazard zonation delineates areas where the potential for damaging earthquake consequence is sufficient to require attention in policy development. The most direct way to limit future earthquake loss of property and life is to locate new structures out of harm's way or to assure that they are designed with adequate earthquake resistance. The Department of Conservation's Division of Mines and Geology (DMG) has the responsibility to produce Official Seismic Hazard Zone Maps that portray the four types of hazard: active fault rupture; liquefaction; induced landsliding; and amplified ground motion.

The Alquist-Priolo Earthquake Fault Zone Act (APEFZA) requires the State Geologist to identify and map active faults that have experienced tectonic displacements during the last 11,000 years. With the zones local governments must require developers to investigate whether or not the "footprint" of the process has been in place since 1972 and has provided insights to the state for zoning other types of seismic hazards.

In 1990 the California Legislature established the Seismic Hazard Mapping Act (SHMA) which requires the State Geologist to zone liquefaction and induced landsliding and amplified ground motion hazards. Similar to the APEFZA, local governments must require developers to investigate the extent of the hazards within the zones and consider mitigation of identified hazards in their land-use permitting. SHMA priorities are for the densely populated seismically active coastal regions. Areas to receive first attention involve over 250 7½ minute topographic quadrangles.

Zones with potential for liquefaction and induced landslide hazard zones encompass areas possessing susceptibility to ground failure that can occur when the opportunity is provided by sufficiently intense ground shaking. Thus, the delineation of the hazard zones is through establishment of threshold criteria for liquefaction and induced landsliding susceptibilities and establishing the levels of ground shaking that will cause these effects. Criteria for identifying damaging amplified ground motion conditions are still in development.

Geographic Information Systems (GIS) technology is employed in the hazard analysis of data obtained from existing mapping, geotechnical reports, aerial photo interpretation, water wells and engineering boreholes. Probabilistic Seismic Hazard Analysis (PSHA) evaluate the ground motion.

Means to increase the effectiveness of seismic hazard mapping include: expanding the use of SHMA products in a variety of mitigation actions through improved communication and incentives; and scientific improvements in PSHA analysis techniques, characterization of liquefaction and induced landsliding susceptibility and potential, characterization of conditions associated with damaging amplification of ground motion, techniques of blind-thrust fault location, and techniques of assembling geotechnical data in user-friendly electronic data files.

These challenges and opportunities can be addressed by partnerships with earth scientists in the U.S. and by U.S./Japan cooperation.

I. Topic Discription and Policy Issues

In the United States (U.S.), state governments are generally charged with the responsibility of establishing laws and ordinances that provide standards for maintenance of public safety and orderly community development. Municipal and county governments generally have the responsibility to regulate building construction and land use. Seismic hazard zonation delineates areas where the potential for damaging earthquake consequence is sufficient to require attention in policy development. The most direct way to limit future earthquake loss of property and life is to locate new structures out of harm's way or to assure that they are designed with adequate earthquake resistance.

In California, the primary use of seismic hazard zonation is in the local government process of land use and construction permitting. The four types of earthquake hazards that are zoned include:

- Active fault rupture
- Liquefaction
- Induced landsliding
- Amplified ground motion

The Department of Conservation's Division of Mines and Geology (DMG) produces official seismic hazard zone maps that portray the four types of hazard. The maps are required to be incorporated into the general plans of all local governments and used in land-use and construction permitting.

Because zone maps portray the geographic distribution of hazardous conditions, they can also be used in emergency response management and effective post-earthquake recovery. Seismic hazard zoning is also a crucial step in the estimation of future economic losses using the anticipated performance of exposed structures together with the hazard conditions associated with their location.

This paper outlines the developmental history of seismic zonation in California--its present status; guidelines and regulations; current challenges and opportunities that can further its effectiveness; options for future partnerships between local, state and federal government; and prospects for cooperation between the United States and Japan in this important area.

II. Background

State of California requirements that local government limit earthquake loss began with development of building code regulations in 1933 following the Long Beach earthquake. Passed in 1972, following the San Fernando earthquake, the Alquist Priolo Special Studies Act (amended in 1993 to become the Alquist Priolo Earthquake Fault Zone Act [APEFZA]) requires the State Geologist, chief of the Division of Mines and Geology, to identify and map active faults at a scale of 1:24,000. Under the Act (Public Resources Code § 2621 to 2630), regulations and guidelines have been established that specify that APEFZA zone boundaries will parallel active faults at a distance of approximately 500 feet on each side. Active faults have experienced tectonic displacements during the last 11,000 years. Within the zones, local governments must require developers to investigate (usually by trenching) whether or not the "footprint" of the proposed structure would be located on the trace of a concealed active fault. An offset of the footprint of a proposed structure by at least 50 feet from an active fault is required. When buildings located within zones are sold, the seller is required to inform the purchaser if the property is within a zone.

Since 1972, DMG has established APEFZA zones in over 570 7½ minute topographic quadrangles. An independent 1991 evaluation of the effectiveness of the APEFZA determined that local governments are complying with the investigations and mitigation requirements and have avoided placement of structures for human occupancy on active faults in tens of thousands of permitting decisions. The Act also requires that local governments file all of the reports of developer investigations with the State Geologist. This has created an extensive data base that is used in new studies. A sector of the earthscience consulting community that is necessary to conduct the required investigations and to critique them for local government has also developed as a consequence of APEFZA. The APEFZA fault zone maps are employed in many ways that are not specified in the Act. Zone maps are used in selection of sites and in earthquake resistant design decisions in public schools, hospitals, utilities, dams and other critical facility construction.

In the late 1980s, DMG conducted a survey of constituencies including the insurance industry, local governments, and property owners to evaluate their hazard information needs and the best manner in which they could be served. It was concluded that a zoning program similar to the APEFZA would be a successful way of employing liquefaction, induced landsliding and amplified hazard information in earthquake loss reduction. In 1990 following the Loma Prieta earthquake, these insights were used by the California Legislature to establish the Seismic Hazard Mapping Act (SHMA, Public Resources Code § 2690-2699.2) which requires the State Geologist to identify these hazard zones. Similar to the APEFZA, local governments must require developers to investigate the extent of the hazards within the zones and consider the results in their land-use permitting. Guidelines for creation of the zones, conducting geologic investigations and the means of mitigating identified hazards have been developed through the State Mining and Geology Board by a technical advisory committee comprised of statutorily specified expertise.

III. Implementation

SHMA specified that the $2.7 million annual funding for zone mapping would come from a small portion of building fee permits collected for new construction by local governments and a surcharge on the California Residential Earthquake Recovery Fund (CRERF) that was intended to cover deductible losses for insured property owners whose homes were damaged by future earthquakes. Beginning in 1990, with the reduced construction activity and continuing in 1991 with the elimination of the CRERF, SHMA funding dropped to about $800,000--less than one-third of the original expectation.

SHMA priorities are for the densely populated coastal regions in seismically active areas to receive first attention involving over 250 7½ minute topographic quadrangles. In 1994, the Governor's Office of Emergency Services (OES) arranged with the Federal Emergency Management Agency (FEMA) for DMG to receive a mitigation grant to accelerate the zoning of 38 7½ minute quadrangles in Ventura, Los Angeles and Orange Counties which were in the Presidentially declared disaster area impacted by the Northridge earthquake. The availability of three-to-one funding for state investment in zoning for this mitigation grant has accelerated the rate of zoning significantly. The Official Seismic Hazard Zone maps for all of the quadrangles will be released before the middle of 1998. In its executive report on the Northridge earthquake, "Turning Loss to Gain," the state Seismic Safety Commission has recommended that the zoning of the highest priority areas be completed by 2005. In order to be accomplished, this will require a sustained increase in the available state funding beyond the three-year duration of the current OES-FEMA mitigation grant.
Sixteen liquefaction and induced landsliding reconnaissance maps were released in February 1996 and six official zone maps will be released in early 1997. The SHMA requires that at least 180 days be required for a combination of public comment and subsequent DMG revision. Reaction to the maps by local government, the consulting community and other potential users has been positive.

SHMA Guidelines and Regulations:

Zones with potential for liquefaction and induced landslide hazard zones encompass areas possessing susceptibility to ground failure that can occur when the opportunity is provided by sufficiently intense ground shaking. Thus, the delineation of the hazard zones is through establishment of threshold criteria for liquefaction and induced landsliding susceptibilities, as well as for levels of ground shaking that will cause these effects. Zones are established enclosing areas in which the criteria thresholds are exceeded. SHMA zones are not separated into levels of relative severity of hazard as are many of the maps published in topical studies. Public resources are employed to establish zones that are documented to have sufficient potential hazard to justify expenditure of private developer funds to provide site specific investigations to determine the extent of the hazard at locations where types of construction projections (defined by SHMA) are proposed. Projects include residential housing developments of four or more units and large structures for human occupancy.

To appraise the shaking opportunity for ground failure, the advisory committee recommended the development of probalistic seismic hazard analysis (PSHA) maps displaying the peak ground acceleration (pga) and the spectral ground motion for various parameters at 0.3, 1 and 3 seconds for exceedance probabilities of 10 percent in 50, 100 and 500 years on soft soil (alluvium), firm soil and rock sites. PSHA requires the use of computer-based Geographic Information System technology (GIS). DMG began preparing these maps on a statewide basis during the same period as the U.S. Geological Survey (USGS) began the 1997 National Earthquake Hazard Reduction Program (NEHRP) ground motion maps of the entire country. DMG had a great deal of information on California active faults from its APEFZA mapping. A partnership was proposed to the USGS suggesting that state and USGS efforts be combined using their data together with information from academic research to jointly develop the 1997 California NEHRP map. In addition to reaching a consensus on fault parameters and earthquake probabilities, collaboration allows agreement on other elements of PSHA analysis such as attenuation rates. Such interaction assures no duplication of effort and eliminates confusion or inconsistency by development of a single product that can be used as a standard reference in the state zoning as well as in future earthquake investigations in the public and private sectors. This joint project is out for public comment and will be released in the fall of 1996. Both digital and hard copy versions of the maps will be available.

Criteria for liquefaction susceptibility recommended by the advisory committee include groundwater saturation at depths of less than 40 feet in artificial fill, unconsolidated Holocene sediment deposits, and localities where there is geologic evidence of fissuring, differential settlement, sand blows or lateral spreading associated with previous earthquakes. In identifying liquefaction susceptibility, the distribution of geologic units, characterization of their age and physical properties are derived from previous mapping, aerial photography, water well and engineering borehole records, and geotechnical investigations. These data are evaluated and integrated using GIS technology to create digital map products. The shaking opportunity threshold to establish liquefaction zones is in excess of 0.4g horizontal pga on alluvial sites with 10 percent probability of exceedance in 50 years.

Earthquake induced landsliding susceptibility criteria include slope conditions as the context for the categorization of geologic units based upon their strength and other physical characteristics, evidence of previous slide activity and structural features such as bedding and joint attitudes. Shaking opportunity is set at horizontal pga in excess of 0.4g at an exceedance probability of 10 percent in 50 years.

The criteria for zoning amplified ground motion are still under development in association with the advisory committee.

The SHMA zone maps are available in hard copy at 1:24,000 and as digital products for use by local government and all other parties. All of the data employed in the GIS analyses will also be available electronically to all users on the Internet. This arrangement adds to the cost-effectiveness of DMG SHMA activities since there has been no regional integration of geotechnical data. The results should contribute to the rigor and comprehensiveness of all future site-specific geotechnical investigations. It is anticipated that the SHMA maps and data will have an even more diverse group of collateral users in addition to local governments than have been established by the APEFZA products. The SHMA materials should be extremely important to all parties involved in loss estimation.

The SHMA electronic file also forms a valuable complement to the DMG Strong Motion Instrumentation Program (SMIP) file that is already on the Internet. The SMIP file contains time histories and processed data from its statewide monitoring of ground motion associated with significant earthquakes in the state. These data have already contributed, and will continue to contribute, significantly to the refinement of attenuation curves that are crucial to reliable PSHA analysis.

Current Challenges, Opportunities and the Need for Partnerships:

The two principal areas of challenge and opportunity for SHMA activities in assuring their cost-effectiveness are in extending the use of SHMA products and improving the science insights applied.

Improvements in cost-effectiveness depend upon:

- Extensive use of SHMA products in a variety of mitigation actions. The mandated requirements that local governments use in their land-use planning and permitting process and the conductance of geotechnical investigations within the hazard zones guarantee a certain level of use. California further benefits from an effective infrastructure to facilitate the implementation of the use of SHMA products including a capable consulting community to carry out the required investigations, as well as a vigorous USGS and academic community to carry out research on earthquake issues. To fully respond to these opportunities to enhance cost-effectiveness, there needs to be an increasing effort to communicate with the parties responsible for mitigation of loss based on the hazards that have been identified. The products should be put together with as much scientific consensus as possible in order to maximize their credibility. The SHMA files should be continuously improved to make them more user-friendly and expedite their application in mitigation. There must be a continuing effort to reduce the costs of SHMA products and services. Partnerships with other parties need to be explored as part of this effort. Improvements should be also be sought in the effectiveness of mitigation techniques applied to identified seismic hazards. Current discussions about the use of fault information from the 1997 NEHRP ground motion map and other DMG sources in the design requirements of the 1997 Uniform Building Code are also encouraging.

- There are also scientific and technical improvements that can contribute to greater cost-effectiveness of the SHMA. These include maximizing the expansion of the empirical ground motion data base by effective improvements in the monitoring of future earthquakes and using these data to better understand site effects and attenuation. The more direct inputs to PSHA analysis that should be continually upgraded include characterization of the fault rupture process and the effects that it exerts on resulting ground motion and reducing uncertainties in the estimation of earthquake sizes and probabilities of future events. Continuing work is needed in the techniques to locate, define and estimate the earthquake potential of blind thrust structures. Improvements are also still possible in characterizing liquefaction and landsliding susceptibilities. A consensus still needs to be developed regarding characterization of conditions associated with damaging amplification of ground shaking. The influence of uncertainties in the determination of input parameters to PSHA analysis on the rigor of the conclusions needs to be explored. The more accurately the SHMA analyses portray the hazards, the more effective their use will be in mitigation design and the more accurate the use of derived loss information will be for the insurance policies and decisions that are so vital to recovery and the justification of mitigation. Partnerships are also feasible and important in the scientific activities associated with the SHMA process as the interaction between DMG and the USGS on the 1997 NEHRP ground motion map.

Cooperation between the U.S. and Japan:

State and federal scientists in the U.S. should explore a number of possible means of cooperating in efforts to improve seismic hazard zonation and their effective use in mitigation. Areas to be explored include:

- Improvement of PSHA analysis techniques and understanding the influence of parametric uncertainties on the rigor of conclusions;
- Improvement of characterization of liquefaction susceptibility and potential;
- Improvement of characterization of earthquake induced landsliding susceptibility and potential;
- Improvement of characterization of damaging amplified ground motion susceptibility and potential;
- Improvement in techniques of blind-thrust fault location and characterization;
- Improvement in techniques of assembling geotechnical data in user-friendly electronic data files for use by a broad community.

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